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IV. *An Account of Observations made of the Variation of the Horizontal Needle at London, in the latter Part of the Year 1722, and beginning of 1723. By Mr. George Graham, Watch-maker, F. R. S.*

THE Figure of the three Needles, with which the Experiments were made, was prismatick ; their Lengths were nearly 12,2 Inches ; their Ends, which pointed to the Divisions, being filed to an Edge, which made a fine Line perpendicular to the Horizon. The Caps of two were of Chrystal, the other of Glafs ; they were well polished on the Inside, in that Part which touched the Pin they moved upon. The Box was Brass, and of a Breadth sufficient to admit of 20° on each Side the middle Line, and covered with a piece of ground Glafs. The circular Arches at the Ends were raised so much above the Bottom of the Box, as to have their upper Surfaces, upon which the Divisions were cut, lie in the same Plane with the Needle, and at such a Distance from each other, that the Needle might play freely between them. A few of the Degrees at the North End were divided into six equal Parts, each Division being $10'$. It was easy, by the help of a Convex Glafs, to determine the pointing of the Needle to less than a Quarter of these Divisions, or to about $2'$ of a Degree. The Pin, upon which the Needle moved, was of Steel hardned, and ground to a fine Point ; and by a Spring placed in the Box, the Needle might be raised from off the Point, and let down again at Pleasure, without removing the

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Glafs,

Glass, or disturbing the Box. By this means both the sharpness of the Point, and polish of the Cap were better preserved from injury, when there was occasion to move the Box. A small piece of Brass was made to slide upon that End of the Needle which pointed to the South, for readily bringing it to an horizontal Position ; for according to the different strength of the Touch, the North End of the Needle will dip more or less. The bottom Plate of Brass was a little broader and longer than the Box, and its Edges made Lines exactly parallel to the middle Line of the Divisions ; and for the greater security of placing the Box in a right Situation, there was a Brass Ruler of thirty Inches long, having its Edges even and parallel, except part of that Edge which was applied to the Side of the Box which was a little filed away on the Middle, that the Side of the Box near its Ends only might touch the Ruler. By this Contrivance the two Points of Contact were as far asunder as the length of the Box would admit of, and the other Edge of the Ruler making a longer Line than the Side of the Box, afforded a better Direction for giving it the same Situation.

For determining the Quantity of the Variation, I got a Meridian Line stretched upon the top of the House, between the Rails of the Leads, which were above fifteen Foot asunder, and the Line was a little more than thirty-nine Inches above the Leads. As this Line was fastned to two Pieces of Brass that were fixed in the Rails, and was above fifteen Foot long, no sensible Error could arise in putting it up at any Time. The Compass-Box was placed upon a Wooden Stool, with three Feet, that had nothing of Iron about it, and its Top set level by a Plumb-Rule. But find-

ing that in the open Air the Wind gave some Disturbance, I put up another Line, after the same manner, in a Room two pair of Stairs high ; this Line was about the same length with the other, and thirty-nine Inches above the Floor. Some time after I put up a third Line, of the same Length, in the Room over this. By the Method made use of in fixing these Lines they could not differ above 2' of a Degree from the Meridian, or from one another. Before I had made any Trials, I imagined no other Difference would arise than what might be occasioned by the Friction of the Needle upon the Point it was to move upon, and having found that considerable in all the Needles that I had taken notice of, I took more than ordinary Care to provide against it, and succeeded beyond my Expectation. For I have several times observed all the three Needles return so exactly to the same Place, that I could not perceive the least Difference ; as likewise all three to agree very nearly about the same Time, when they have been placed in the same Box immediately one after another, the Box remaining unmoved. The first Needle I made, was a little above three tenths of an Inch broad, about ,06 in thickness, and weighed about an Ounce Troy, the Cap of Chrysal. After some Trials with this Needle, it was made narrower, not to exceed half a tenth of an Inch, and it then weighed five Penny Weight and five Grains. The second Needle was at first about three tenths of an Inch broad, and ,04 thick, the Cap of Glass ; and after several Trials, it was made so much narrower, that its Breadth was a little less than its Thickness, and it weighed two Penny Weight and five Grains. The third was nearly of the same Dimensions with the second, and weighed two Penny Weight and three Grains.

When

When the two first Needles were made narrower, care was taken that the Files made use of for filing the North Ends, touched not the South Ends; and after they were made lighter, I tried them both, before they were fresh touched upon the Stone, and found no sensible Difference in their Direction. The reason of making the two first Needles so heavy, was to try whether they would return more constantly to the same Situation than lighter ones. But notwithstanding each of them would settle very exactly in the same Place, for a great Number of Trials made immediately one after another, yet I found them at different Times to differ considerably from their former Directions.

This occasioned my making them narrower, fearing their Breadth had been some way concerned in this Irregularity. But after the Alteration, I found the same thing happened, though I could find nothing of it to proceed from any Friction upon the Point. This made me prefer the lighter Needles, as less apt to injure the Point they moved upon, and as exact in returning to the same Situation. After many Trials, I found all the Needles I made use of, would not only vary in their Direction upon different Days, but frequently at different times of the same Day; and this Difference would sometimes amount to upwards of half a Degree in the same Day, sometimes in a few Hours. And this Alteration I observed, whether the Needles were drawn aside immediately before the Observation, or suffered to remain undisturbed. For I have left the Box standing for several Days together, without ever disturbing the Needle, only have taken notice what it pointed at, and the Time of the Day, and I could sometimes perceive in a few Minutes a very sensible Alteration. But whether it stood near its
greatest

greatest or least Variation, or whether I drew the Needle to one Side with a Key a few Degrees or a greater Number, it would constantly return to the same Place it stood at immediately before. Sometimes I have taken the Needle out of the Box, and put it in again, and this I have repeated several times in the space of an Hour. At other times I have taken down the Box from off the Stool, and put it up again, but have found no Alteration in its Direction; so that I found it of no Consequence, whether the Needle was drawn aside or let alone, the shaking of the Floor by walking upon it, or the trembling of the House by the Coaches in the Street, was sufficient to overcome the small Friction upon the Point. When I made the Observations, I was very careful to have no Keys, nor Iron about me, that could affect the Needle.

The Box was placed in the Room above the Distance of six Foot from the nearest Wall, and above thirteen Foot from the Grate in the Chimney, and no Iron could at any time be brought near it without my Knowledge. Yet, after all, I am not satisfied that it was out of the reach of Iron, and that the Variation shewn by it is the true Quantity; but I am very sure there was no Change of Circumstances in the Room that could affect it, for if there were any such Materials in the Wall, or Floor, their Distances and Situations continued the same. But for a farther Confirmation of this Irregularity, I put one of the Needles into a Wooden Box, with a few Degrees divided as the other, and placed it at the same Meridian Line, at the Distance of three Foot and a half from the other, and found both Needles nearly agreed in their Alterations. The Needles were all touched by that excellent Loadstone presented to the Society by the Right Honourable

ble the Lord *Paisley*. It may not be improper to take Notice, that the Needles were not touched upon the naked Stone, but with its Armour on, generally upon that Part of the Capping nearest the Poles ; but I could not find a Difference in the Direction, by touching upon another Part. I may add, that when I have observed the Needle increasing, or decreasing in its Variation, I have very frequently, with a Key, drawn it the contrary Way several Degrees, and then, by letting it return very gently, till it has been within a Degree, or less, of the Place it stood at immediately before, I have there stopt it for some time, by holding the Key at a proper Distance ; and withdrawing my Hand gradually, have tried to make it stand short of its former Place, but could never succeed. By this Method, and several others made use of, I am well assured these Changes in the Direction are owing to some other Cause than the Friction of the Needle upon the Pin ; but what that Cause is I cannot say, for it seems to depend neither upon Heat nor Cold, a dry or moist Air, clear or cloudy, windy or calm Weather, nor the Height of the Barometer. The only thing that has any appearance of Regularity, is, that the Variation has been generally greatest, for the same Day, between the Hours of Twelve and Four in the Afternoon, and the least about six or seven in the Evening.

March

March 8. 1722.

This Day a piece of Brafs was fixed to a Wooden Box, and a few Degrees were divided into 10' each, as in the Brafs Box, to try if both Needles would be alike affected in the several Alterations. This Wooden Box was placed at the same Meridian Line, and about the Distance of 3½ Feet from the other.

Brafs Box.	Needle 2=5.		Needle 5=5
		h.	
March 8.	14° = 30' —	3 = 00'	14° = 25' +
	14 = 20	3 = 15	14 = 20
	14 = 15 +	4 = 00	14 = 10
	14 = 20	4 = 15	14 = 15
	14 = 25	5 = 00	14 = 20
	14 = 25	5 = 30	14 = 20
	14 = 15	5 = 45	14 = 10
	14 = 00	5 = 57	14 —
	14 —	6 = 8	13 = 55
	13 = 50	6 = 15	13 = 40
	14 = 20	6 = 38	14 = 15 +
	14 +	6 = 48	14 = 00
	14 = 00	6 = 54	14 —
	14 = 5	7 = 5	14 +
	14 = 10	7 = 15	14 = 5
	14 +	12 = 00	14 +

March

Brafs Box.	Needle 2=5.		Needle 5=5.
<i>March 9.</i>	14° = 10'	9 ^h = 30'	14° = 10'
	14 = 10 +	10 = 00	14 = 10 +
	14 = 10	10 = 15	14 = 10
	14 = 10 +	10 = 30	14 = 10 +
	14 = 15	11 = 00	14 = 15 —
	14 = 00	8 = 15	14 = 00
	14 = 00	11 = 50	14 = 00

<i>March 10.</i>	14° = 10' +	10 ^h = 00'	14° = 10'
	14 = 15	11 = 00	14 = 10 +
	14 = 15	12 = 00	14 = 10 +
	14 = 15 +	12 = 45	14 = 10 +
	14 = 15 +	1 = 00	14 = 10 +
	14 = 15 +	1 = 30	14 = 10 +
	14 = 15 +	1 = 45	14 = 10 +
	14 = 15 +	2 = 00	14 = 10 +
	14 = 15	3 = 30	14 = 10
	14 = 15 +	4 = 00	14 = 10 +
	14 = 15 —	5 = 30	14 = 10 —
	14 = 10	6 = 00	14 = 5
	14 = 00	6 = 15	14 = 00
	14 —	6 = 30	14 —
	14 +	7 = 30	14 +
	14 = 5	7 = 45	14 +
	14 +	12 = 00	14 +

March 30.

The Needle $2=5$ which was in the Brafs Box, was this Day put into the Wooden Box, and a new Needle put into the Brafs Box, Weight $2=3$.

No remarkable Change happened to either Needle till *April* the 5th.

Needle $2=3$ in the Brafs Box.

April 5.

$14^{\circ} = 5'$

$14 = 10$

$14 = 10 -$

$14 -$

$13 = 50 +$

$13 = 55 +$

$14 -$

$14 = 00$

$14 +$

$9^h = 00'$

$1 = 30$

$5 = 30$

$8 = 15$

$8 = 37$

$9 = 45$

$10 = 25$

$10 = 45$

$11 = 00$

Needle

$2=5.$

$14^{\circ} + 00'$

$14 = 5$

$14 +$

$14 -$

$13 = 45$

$13 = 45 +$

$13 = 50$

$13 = 55$

$14 = 00$

The first Column shews the Variation of the Needle in the Brafs Box. The third the Variation of that in the Wooden Box. The second Column shews the Time, by the Clock, when the Observations were made.

April

April 15. 1723.

14° = 30' —	9 ^h = 00'
14 = 30 —	10 = 00
14 = 30	11 = 30
14 = 30 +	12 = 30
14 = 30 +	1 = 30
14 = 30	3 = 30
14 = 30	4 = 10
14 = 30 —	5 = 30
14 = 20	6 = 18
14 +	7 = 8
14 = 00	7 = 50
14 = 00	8 = 15
14 = 15 +	8 = 20
14 = 15 +	8 = 40
14 = 15 +	12 = 15
14 = 00	12 = 27
14 = 00	12 = 32
14 = 00	12 = 35
14 = 00	12 = 43

Wind at S. W.

April 16.

14° = 30' —	9 ^h = 30'
14 = 30	11 = 00
14 = 30	12 = 00
14 = 30 +	1 = 10
14 = 30 +	1 = 40
14 = 30	2 = 45
	R 2

14° = 30'	5 ^h = 00'
14 = 30 —	6 = 00
14 = 25	6 = 20
14 = 20	6 = 30
14 = 15	6 = 35
14 = 10	6 = 40
14 = 10 —	6 = 45
14 = 5	6 = 49
14 = 00	6 = 57
14 = 00	7 = 10
14 +	7 = 20
14 = 5 +	7 = 30
14 = 10	7 = 45
14 = 15	8 = 00
14 = 15 +	8 = 20
14 = 20 —	8 = 30
14 = 25 +	9 = 00
14 = 25	12 = 12
14 = 25	12 = 21

Day warm, cloudy in the
Morning, Evening clear.*April 19.*

14° = 30' —	8 ^h = 35'
14 = 30 —	9 = 00
14 = 30 —	1 = 30
14 = 30 —	2 = 00
14 = 30	3 = 30
14 = 30	4 = 00
14 = 20	5 = 00
14 = 25	5 = 38
14 = 25 +	5 = 45
	14 =

14° = 30' —	6 ^h = 00'
14 = 30 —	6 = 45
14 = 25	7 = 00
14 = 20 —	8 = 00
14 = 20	9 = 00
14 = 20 +	10 = 00
14 = 25	11 = 00
14 = 25	11 = 15

Day warm, Wind at East,
some Thunder in the
Afternoon.

May 2.

14° = 25'	9 ^h = 30'
14 = 30 +	10 = 30
14 = 35 —	11 = 30
14 = 35 +	1 = 00
14 = 35 +	1 = 52
14 = 40 +	2 = 30
14 = 20	3 = 30
14 = 25	3 = 45
14 = 30 —	4 = 00
14 = 25 +	6 = 45
14 = 20	7 = 00
14 = 30 —	7 = 35
14 = 20 +	12 = 50

Day cold, Wind at East.

May 3.

14° = 10'	9 ^h = 30'
14 = 15	11 = 10
14 = 15 +	12 = 40
14 = 15 +	2 = 20
14 = 10 —	5 = 20
14 = 10	6 = 5
14 = 10	6 = 45
14 = 10 —	7 = 5
14 = 5	7 = 15
14 +	7 = 30
14 = 00	7 = 42
14 +	8 = 00
14 +	9 = 38
14 +	10 = 15
14 +	11 = 00

Day cold, Wind Easterly.

May 4.

14° = 5'	9 ^h = 15'
14 = 5	9 = 30
14 = 10 +	1 = 35
14 = 10 +	3 = 17
14 = 10 +	3 = 50
14 = 10	4 = 55
14 = 10	6 = 00
	14 =

$14^{\circ}=00'$	$8^h=15'$	$14^{\circ}=15' +$	$12^h=30'$
$14 +$	$1 = 00$	$14 = 20$	$1 = 57$
Windy at East.		$14 = 20$	$2 = 45$
		$14 = 20$	$3 = 25$
		$14 = 20 -$	$4 = 35$
		$14 = 15 +$	$5 = 30$
		$14 = 15 +$	$6 = 10$
		$14 = 15 -$	$12 = 7$
<hr/> <i>May 5.</i>			
$14^{\circ}=10' +$	$9 = 30'$		
$14 = 15$	$10 = 45$	Day clear, Wind at East	

All these Observations are of the lightest of the three Needles, the Compass Box remaining unmoved the whole time. From *February 6. 1722.* to the 10th of *May* following, I made above a thousand Observations in the same Place; and the greatest Variation Westward, was $14^{\circ}=45'$, and the least — — $13^{\circ}=50'$. It was seldom less than 14° , or greater than $14^{\circ}=35'$.
